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STRENGTH OF BRITTLE ANISOTROPIC MATERIALS AT SHOCK-WAVE LOADINGS

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SUMMARY

From uniform modeling and methodological representations the comparative analysis of behavior fragile both plastic isotropic and anisotropic materials is carried out. Influence of orientation of properties, shock-wave processes on the mechanism of macrodestruction of anisotropic bodies is investigated. Results of numerical researches are compared to experimental data. On the basis of the created models and techniques a number of applied problems are solved.

INTRODUCTION

Small number of works, devoted to investigations on anisotropic material behavior at impact loadings testifies that this problem is weakly studied. At the same time, anisotropic materials find wide application, especially in connection with development of modern technologies, which allow to obtain materials with preset properties. To provide optimum use of material properties in various constructions, it is necessary to consider loading conditions under which it will be used, and to preset material properties and their orientation on this basis. Consideration of material properties directivity is especially important for constructions, operating under extremal conditions, experiencing intense dynamic loads i.e. equipment for aviation and spacecraft, containers for storage and transportation of explosives and toxic substances.

STATEMENT OF THE PROBLEMS

Let's consider pulse and impact loadings of orthotropic materials. The problem is solved by the finite elements method in three-dimensional statement in *XYZ* Cartesian coordinates system. Symmetry axes of orthotropic material coincides with coordinates systems ones. The behavior of orthotropic material is considered in framework of phenomenological approach [1-4]. The orthotropic material has following mechanical properties' relations: $E_x>E_y>E_z$, $\sigma_{bx}>\sigma_{by}>\sigma_{bz}$, where E_x, E_y, E_z are modulus of elasticity, σ_{bx}, σ_{by}, σ_{bz} are ultimate strength in correspondent directions.

DISCUSSION OF RESULTS

All-round pulse compression of orthotropic ball

Homogeneous orthotropic and isotropic balls with diameter of 10mm was subjected to compression with pulse pressure of 1GPa during 3μsec. Already at the time moment of 0.6μsec in *ZX* cross section (where there is most significant difference between characteristics), the distribution of stress (fig. 1) illustrate the origin of heterogeneous picture of strain-stress state of the orthotropic ball. At this moment, the stresses achieves maximum values (-2GPa) near at ball poles on Z-axis. In this case the ball failure arises in the region of maximum stresses (fig. 2). With time the strain-stress state of anisotropic ball differs from strain-stress state of isotropic ball more strongly.

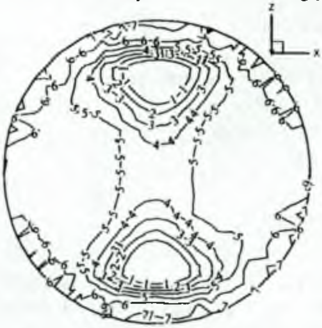

Fig. 1. Distribution of stress isolines σ_x. t = 0.6 μsec. 1: -2GPa, 2: -1.8GPa, ..., 8: -0.6GPa. t =2.8μsec.

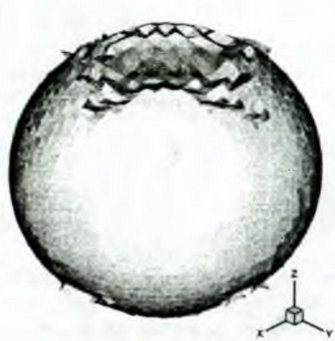

Fig. 2. Volume configurations of orthotropic ball.

The destruction isotropic ball occurs differently. It is illustrated by field of mass velocities and distribution isolines of the pressure σ_x, given in section ZY in the fig. 3 and fig. 4. The compression of the material of the ball occurs up to t=1.6мкс. To this moment of time as a result of spherical symmetry occurs focusing of the wave of compression at the centre of the ball, where the compressing pressure exceed amplitude of an external pulse, reaching -3GPa. In the vicinity of the centre of the ball the material passes in the hydrodynamic condition, saving durability only to compression, the diameter of this zone makes 4.4мм. After cancellation of compressing pressure to the centre of the ball begins to be distributed the relief wave. In relief wave the material in the central part of the ball weakened by the wave of compression, collapses completely - in a vicinity of the centre of the ball the cavity by the diameter 4.4мм is formed. The destruction of the material in the wave of relief, that evidently shows a fig. 4, where the field of velocities in the ball is submitted at the moment of achievement by the relief wave of area of the hydrodynamic condition of the material.

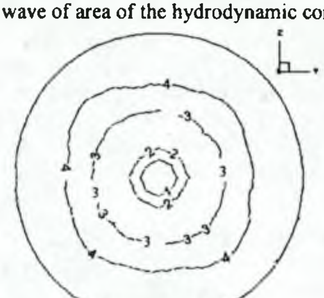

Fig. 3. Distribution of stress isolines σ_x. t = 1.6μsec. 1: -2.4, 2: -2, 3: –1.6, 4: –1.2GPa.

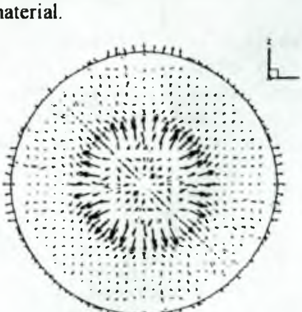

Fig. 4. Field of mass velocities. t = 4μsec.

Impact loading

Let's consider the interaction of steel isotropic striker with orthotropic plate. The influence of orientation elastic and strength properties in the orthotropic material of the barrier on dynamics of its destruction is investigated in view of various meanings of breaking point on compression and tension.

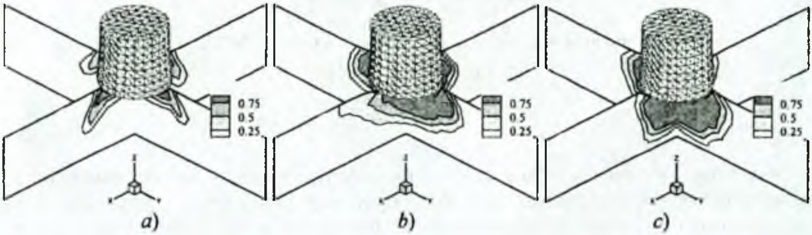

Fig. 5. Distribution of isolines of the relative portion of the destroyed material υ_0=700m/sec, t=5μsec. *a*) initial orientation of orthotropy axes β = 0°; *b*) β = 45°; *c*) β = 90°.

CONCLUSION

The carried out researches have shown, that anisotropy of properties is the essential factor which is necessary for taking into account for the adequate description and the prediction of development of shock-wave processes and destruction in the materials subject to dynamic loadings. The offered model of destruction using tensor-polynomial criterion of the fourth degree, enables to model behaviour of a wide class of anisotropic materials with a various degree of anisotropy. It was stated that the changing orientation of properties causes qualitative changes in mechanisms of macrofailure of anisotropic material.

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